Question #2

- What are the leading technology candidates for implementing communications for these applications?
- Varies by application. Some general groups:
  - Stationary or near-stationary: many media (including DSRC) could service these applications
  - True (high-speed) mobile: DSRC has real advantages, being designed for mobility
  - Safety: Guaranteed access and dedicated band give DSRC a significant edge

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Question #3

- For which applications is DSRC at 5.9 GHz a serious contender?
- Most of them, especially where high-speed operation and/or guaranteed access is a requirement. Since DSRC is probably required for high-speed and safety applications, it makes sense to use it for other applications as well and keep the device count low.

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Question #4

- What are the principal obstacles and challenges for the use of DSRC at 5.9 GHz?
  - Business issues - Affordability, validating the market, breaking the chicken & egg dilemma, liability issues, international standards and markets
  - Technology issues - Ensuring interoperability, providing products at affordable prices, lack of standards(!), rapid pace of change, obsolescence/transition/migration
  - Institutional issues - Same issues as today, but more complex because of more institutions; interoperability!; sunk costs, inertia;
  - Regulatory issues - Normal stuff: band use rules, licensing, etc.

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Question #5

- What role will standards play in creating an interoperable wireless environment, both in general and for DSRC at 5.9 GHz?
- As usual with standards, they are extremely helpful in achieving interoperability, but are not sufficient to guarantee it. A standard with an interoperable profile allows procurement agencies to specify interoperability. Testing is always required to confirm that systems work together properly.

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Question #6

- What is the appropriate role (if any) for USDOT in helping to create the interoperable wireless environment? In promoting standards for this environment? In promoting standards specifically for DSRC at 5.9 GHz?
- Proving the market for enhanced devices [*could* mandate]: *Could* come out and state that current things being done via various communications media *should* get done via DSRC/5.9: *Could* work with auto mfrs to define a standard OEM tag [device needs to help sell the car].
- Hypothetical Scenario: If we had a standard and given DOT's safety mandate (wrt work zone, HRI, hazardous conditions, etc.) ... DSRC seems like obvious (only?) candidate for delivering this information. But not being deployed because not a large volume of equipped vehicles yet. If there were standards, DOT *could* say, to solve these safety problems, it would mandate the presence of an RF tag in all new vehicles). *What about the accompanying infrastructure to communicate with these tags?*

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DOT Role (cont'd)

- Short of a mandate... Looking at Bluetooth™. Would be interesting from oil co. perspective, to accelerate an early version of DSRC so that it becomes an option to be considered.
- Make highway trust funds available to build the safety comm infrastructure.
- Need incentives besides "allowing" use for this infrastructure.
- Seeding the infrastructure to create a pull for rollout of new services & devices, funding standards activities (of general benefit) to accelerate the process.

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DOT Role (cont'd)(2)

- Be careful about trying to be all things to all people (risk ending up being nothing much to anybody in particular).
- Should be a mandate for tags in vehicles; then vehicle needs to be smart; implies computer in vehicle. Propose overall structure with smart cars, infrastructure, and (software based) communications of various kinds.
- Work with a vendor consortium to determine what features could be built that DOT could support/mandate. Encourage such a consortium to move forward Expeditiously
- Provide support to development testing.

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Question #7

- What is the appropriate role (if any) for ITS America in helping to create the interoperable wireless environment? In promoting standards for this environment? In promoting standards specifically for DSRC at 5.9 GHz?
  - Proving the market for enhanced devices, serving as cheerleader for development of interoperable standards
  - Create consortium of users (business focus) (Lee A)
  - FCC is tasked with writing rules for private sector, but doesn't know ITS. Needs to come from industry (ITSA, consortium, etc.) Needs this support pronto.
  - Full range of interested parties need to get involved -- ITSA has outreach responsibility

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Question #8

- What kind of interactions should take place between US DOT and the FCC in creating the interoperable wireless environment? In promoting DSRC and standards for DSRC at 5.9 GHz?
  - None, other than appropriate commenting. ITS flexibility will be enhanced by minimal FCC rules, and intensive interaction by US DOT threatens this minimalist approach.
  - DOT has done of the analysis that ITSA has taken to FCC, but generally not an active role so far.
  - Remember that primary justification for 5.9 allocation was safety-based. DOT needs to get focus on safety so allocation doesn't go away.

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Likely Timeframes

- It's largely a serial process
- Standards development: Jan - Dec, 2000
  - 8 meetings @ 6 week intervals - pretty sporty
- Standards validation: Jan - Jun, 2001
- Vendor design: Jan - Dec, 2001
- Vendor development: Jan - Dec, 2002
- Product on the street: Early 2003

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DOT could / should fund.....

- FCC consultant (band use. channelization)
- Security consultant (encryption requirements)
- Standards editorial contractor (all layers)
- Common needs testing related to 5.9 GHz
  - Environmental
    - ice. snow. slush. sand. dirt. dust
  - Performance evaluation
    - 802.11 protocol. modulation (BPSK. QPSK. other)
  - Validation of (existing) P1455 (L7) standard
  - Validation of (eventual) L1 & L2 stds

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A Market?

- Is there a market for ITS products at 5.9 GHz?
  - YES, potentially a large one
- Why?
  - Bandwidth to support a variety of services
  - Reliable service to support safety applications
  - Wide range of services - from a single device
  - Interoperability by design
  - Multiple sources of supply for interoperable devices

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A Giant Step

- The most powerful thing DOT / ITSA can do is prove the market - and especially that the market is soon / now.
- Then just stand back so you don't get run over.
  - We'll have a standard so fast it'll make your head swim

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A Proposal

- Create a **DSRC INDUSTRY CONSORTIUM**
- *Composed of a small group of affected vendors*
- Issues would include:
  - Promoting DSRC for sensible DSRC applications
  - Pushing 5.9 GHz standards to timely completion
  - Industry commitment to interoperability
  - Issues of mutual concern
    - Windscreen coatings
    - Liability
  - Testing & analysis of mutual benefit
- *Work toward Quick spec/standard, which is then brought back to the community*
- *Does DOT cooperation with this Consortium imply need to involve multiple other technical (wireless comm) alternatives??*

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One-slide summary

- There are only so many ways to say it---

The vendors will build what the market wants to buy - when the market wants to buy it.

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I've talked long enough

Thank

You

Intermec

RULES FOR USE OF THE 5.9 GHz BAND

ITS America Workshop for ITS Applications in the 5.9 GHz Band

December 16-17, 1999

Bob Kelly

Squire, Sanders & Dempsey, L.L.P.

ET DOCKET 98-95

- Report and Order, FCC 99-305 (October 22, 1999)
  - Allocates 5.850-5.925 GHz Band to Mobile Services on a co-primary basis (2.106)
  - Use limited to DSRC operating in ITS Radio Service (fn NG160)
  - To increase traveler safety, reduce fuel consumption and pollution and to advance the nation's economy (para. 5)

Squire, Sanders & Dempsey, L.L.P.

R&O (FCC 99-305)

- Adopts basic technical rules
  - Power limits
  - Unwanted emissions
  - Frequency stability limits
- Defers licensing and service rules and spectrum channelization plans to later proceeding
  - Standards addressing such matters are still under development by DoT (Para. 1)

Power Limits

- The peak transmit output power over the frequency band of operations shall not exceed 750 mW or 28.8 dBm with up to 16 dBi in antenna gain (para. 24).
  - If greater than 16 dBi gain, then peak transmit output power shall be reduced so maximum EIRP shall not exceed 30W
  - Peak transmit power may be increased for line losses provided EIRP does not exceed 30 W

Unwanted Emissions

- We adopt the emissions mask requirements of Section 90.210(k) for DSRC operations in the 5.9 GHz Band (para. 25).
- Depending on the developing DSRC applications, the licensing scheme adopted and the channelization plan, we may need to revisit the emissions limits (para. 25).

Squire. Sanders & Dempsey. L.L.P.

Frequency Stability

- The NPRM proposed to apply the frequency stability requirement of Section 2.1055.
- Since we are not yet able to establish a channelization plan, we will defer any decision on frequency stability requirements to a future proceeding (para. 26).

Squire. Sanders & Dempsey. L.L.P.

DSRC Definition

- The use of non-voice radio techniques to transfer data over short distances between roadside and mobile radio units, between mobile units, and between portable and mobile units to perform operations related to the improvement of traffic flow, traffic safety and other ITS applications in a variety of public and commercial environments (para. 31).

R&O (FCC 99-305)

- Released October 22, 1999
- Published Federal Register November 26, 1999
- Petitions For Reconsideration By December 27, 1999
  - Power limits, emissions mask, DSRC definition?

Service Rules TBD

- Licensing
  - Classification
    - Public Safety
    - Private
    - Commercial
  - Spectrum Channelization Plan
    - Band Segmentation?
    - Unlicensed band?

Licensing

- Auctions?
  - Geographic Areas?
  - Commercial use
  - Unlimited eligibility
- First come, first served?
  - Mutual exclusivity to be resolved?
  - Site specific
  - Eligibility limitations

Technical Rules

- Frequency Stability Requirements
- Emissions Mask
- Power Limits?
- Others?

Squire, Sanders & Dempsey, L.L.P.

FCC Process

- Licensing and Service Rules to be proposed by Wireless Telecommunications Bureau In a NPRM
  - Input from Office of Engineering and Technology
  - Q2, 2000?
  - Comments and Reply Comments
  - Six months to one year for R&O
  - Licensing following R&O

Squire, Sanders & Dempsey, L.L.P.

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DRAFT

ALTERNATIVE TECHNOLOGIES TO DSRC: INITIAL ASSESMENT

I. Introduction/Executive Summary

The United States Department of Transportation (USDOT) has commissioned a special task force on Dedicated Short Range Communications (DSRC) applications and standards. The purpose of this task force is to advise the USDOT on whether they should invest in standards development in the 5.9 GHz frequency band. This band (5.85-5.925 GHz) was recently allocated for Intelligent Transportation Systems (ITS) by the Federal Communications Commission (FCC).

One of the many considerations USDOT has included for the task force is to investigate technical alternatives. other than radio frequency identification (RFID). that might be used to implement prospective DSRC applications. and could potentially erode the market for DSRC products. USDOT is also interested in the relative merits of these technologies. since this will influence their decision to fund development of an ITS standard. The task force is concerned mostly with non-technical issues. and may not be familiar with the latest developments in the wireless communications industry. USDOT has asked Mitretek to produce a white paper to help make the task force members aware of these technologies.

This initial white paper describes several different technologies. some of which are currently available. and some that are expected within the next year or two. These products. listed in Table 1. can be operated in a point-to-point as well as a point-to-multipoint mode. and have the potential to be used for one or more DSRC applications. These products are designed for portable operation (transmitting terminals are either stationary or moving at pedestrian speeds). However. under certain circumstances. they may function at moderate highway speeds. The basic operation. intended use. and technical features will be described as well as the limitations of these products under the FCC rules and regulations. The relative merits of theses technologies will be discussed as well as additional analysis that should be performed to determine which potential DSRC applications might be implemented with these technologies.

Technology	Modulation/Freq.	Data Rate	Specification Owner	Potential DSRC Applications
802.11	FH/2.4 GHz	1-2 Mbps	IEEE	Slow vehicle speed. 10-15 collocated readers
802.11	DS/2.4 GHz	1-2 Mbps	IEEE	Slow-medium vehicle speed. 3 collocated readers
802.11 b	DS/2.4 Mbps	11 Mbps	IEEE	Stationary operation. 2.4 GHz band
802.11 a	OFDM/5 GHz	> 20 Mbps	IEEE	Stationary operation . 5 GHz band. large downloads
Bluetooth	FH/2.4 GHz	108-732 Kbps	Bluetooth SIG	Very short range. 8 active tags per reader
HomeRF	FH/2.4 GHz	1-2 Mbps	HomeRF WG	Similar to 802.11 FH
HIPERLAN	GMSK/5 GHz	24 Mbps	ETSI	Stationary. 5 GHz band. large downloads

Table 1. Summary of Technologies

Acronyms used in Table 1:

- FH-frequency hopping
- DS-direct sequence
- OFDM-orthogonal frequency division multiplexing
- GMSK-Gaussean minimum shift keying
- IEEE-Institute of Electrical and Electronics Engineers
- SIG-special interest group
- WG-working group
- ETSI-European Telecommunications Standards Institute

II. Alternative Technologies

DSRC systems include fixed roadside transceivers that communicate over short distances (between ten and several hundred meters) with small on-board units installed in vehicles, rail cars, freight containers, or any device that needs radio frequency-based identification. Current systems operate at microwave frequencies in an unlicensed mode in bands allocated for Industrial, Scientific and Medical (ISM) equipment. Communications systems considered as DSRC alternatives in this white paper are those that are also capable of short range microwave communications either in a point-to point or point-to-multi-point mode. The new technologies with these capabilities generally fall into two categories, Personal Area Networks (PANs) or Wireless Local Area Networks (WLANs).

The market for PANs is being driven by the large number of cables needed to wire computers (the mouse, the keyboard, speakers, scanners, printers, PC cameras etc.) and the proliferation of mobile computing devices that need to be connected together (palmtops, cell phones, hands-free headsets). PANs are used to create a very localized wireless network to replace the cables needed to integrate these products. The leading technology intended to meet these applications is called Bluetooth.

The market for wireless LANs has literally exploded with the finalization of a suite of standards and dropping costs of microwave components. The leading technologies in this area are HomeRF, HIPERLAN, and several versions of LANs that comply with the IEEE 802.11 protocol suite. Wireless LANs are useful in factories, warehouses, retail establishments, and offices where wiring computers into the corporate network is not cost effective. A newer market that is being pursued for these products is the home market. Families buying second computers would like to tie the computers and peripherals together as well as have the ability to control various devices around the home without adding new wiring.

All of the technologies mentioned above, with the exception of HIPERLAN, operate under Part 15 of the FCC rules and regulations. The main advantage of this operation is that no FCC license is required. However, operation under Part 15 places several restrictions on the design and capabilities of these products.

III. Part 15 Operation

Section 15.247 of the FCC rules governs the operation of license-free devices in three frequency bands allocated for Industrial Scientific. and Medical (ISM) equipment. These bands are 902-928 MHz. 2400-2483.5 MHz. and 5725-5850 MHz. It should be noted that DSRC systems currently in operation in the United States use the 902-928 MHz band as non-multilateration devices in the Location and Monitoring Service (LMS) (many frequency allocations are shared by several services). The new ITS frequency band for DSRC is at 5850-5925 MHz. Devices used in the ITS band will be licensed. allowed higher transmit power than Part 15 devices. and will have primary status. which means each installation will be assigned its own channels and will be protected from interference. Also. spread spectrum modulation is not a requirement.

One of the restrictions of Part 15 is that the license-free devices must not interfere with other authorized services in the frequency band. and must accept any interference received from these services. They must also accept interference from other Part 15 devices. If a Part 15 device causes harmful interference to an authorized service. it must cease operation until the interference is corrected. In order to decrease the likelihood of interference as well as permit operation at higher power levels. the FCC requires the use of spread spectrum modulations for these devices in the ISM frequency bands. There are two basic forms of spread spectrum allowed: frequency hopping and direct sequence. This is important for potential DSRC applications since the number of co-located systems. the distance at which you can reuse a channel. and the performance in a mobile environment is different for the two modulations.

Frequency hopping (FH) systems spread their energy by changing the center (or "hopping") frequency of transmission in accordance with a pseudorandom generated list of channels. In the 2.4 and 5.8 GHz band. they may transmit with a maximum output power of 1 watt and must hop over a minimum of 75 channels. with each channel not exceeding 1 MHz. The average time on any frequency must be less than 0.4 second within a 30 second period. In the 902-928 MHz band. the channel bandwidth must be less than 250 KHz and must use at least 50 channels to be able to use 1 watt of transmit power.

Direct sequence (DS) systems spread their energy by combining the original data stream with a spreading code that has much higher data rate. The spreading code is based on a pseudorandom sequence and has the effect of spreading the energy over a much wider bandwidth. This allows for fewer channels within the allocated bandwidth, but the interference is at a much lower level. Part 15 requires the processing gain to be at least 10 dB. which establishes the minimum level interference immunity of the systems.

For devices using either modulation, the maximum transmitter output power is 1 watt and the maximum effective radiated power is 4 watts. If antennas with a gain greater than 6 dBi are used, the transmit power has to be reduced. The one exception to this rule is for devices in the 5.8 GHz band operating in a fixed point-to-point mode. These systems have no limit on the gain of directional antennas used. This explains why some license-free systems will advertise communications distances on the order of several miles. Wireless LANs used for communicating with portable devices typically use omni-directional antennas and communicate over distances of several hundred meters.

There is a docket before the FCC requesting rule changes to Part 15. Among the considerations is a request by HomeRF to allow changes to the bandwidth restrictions that will enable data rates sufficient to transmit CD-quality audio and compressed MPEG2 video streams from home PCs to portable devices. The FCC is currently considering these changes and is soliciting comments.

IV. 802.11 Systems

The 802 Committee of the IEEE publishes standards for LANs. There are many LAN protocols that have been standardized by this committee. For example, the common Ethernet LAN standard is 802.3. Wireless LANs are incorporated in 802.11. There are currently 3 different suites of IEEE 802.11 wireless LANs: 802.11, 802.11a and 802.11b. The reason there are multiple suites is due to improvements in capabilities and data rates. 802.11 and 802.11b are completed standards.

1. 802.11

802.11 LANs are built around cells called basic service sets. The base station in each cell is called an access point, and access points can be connected to each other and subsequently into fixed ethernet or other backbone communications in what is called a distribution system. Laptop computers and other devices communicate via the access point using small wireless LAN cards that are in PC card (or PCMCIA) form. Devices can communicate directly, without going through an access point, in what is called the ad-hock mode. These LANs support either 1 or 2 Mbps data rates and use either DS or FH spread spectrum or infra red links. The RF versions of this standard operate in the 2.4 GHz ISM band, where 83.5 MHz of bandwidth is available.

FH systems use the entire 2.4 GHz ISM frequency band. There are 79 hop frequencies and theoretically, 12 access points can be collocated, each with a unique hopping sequence. Some vendor estimates indicate up to 15 access points can be collocated, but hop collisions will occur which result in a reduction in overall throughput due to the need to retransmit packets.

The DS systems use approximately 11 MHz of bandwidth to transmit the signal. A maximum of 11 channels is available, but only 3 are non-overlapping. This means that only 3 access points can be collocated. Channels can be reused by providing coverage in a cellular fashion where adjacent cells use non-overlapping channels. Also, due to better receiver sensitivities in DS systems, cells using the same channel can be packed 4 to 8 times more densely for DS than FH systems.

These LANs, intended to be wireless replacements for ethernet, were designed for access points and user terminals to be fixed or portable, but stationary when in use. The waveforms were designed for operation in propagation environments typical of office buildings, warehouses and campuses. The minimum processing gain needed to qualify as a spread spectrum Part 15 device is used. This will keep prices lower, but results in systems that are less robust. Some users have mounted these devices in moving vehicles, but discussions with the IEEE 802.11 committee indicate that performance is not guaranteed in this mode, and effective operation at speeds above 30 MPH may not be feasible. Transit companies have experimented with using these devices to download data from busses at a depot or fuel yard. Since the busses are either stationary or moving very slowly during the data transfer, this technology may work very reliably for this application.

2. 802.11 b.

802.11 b is based on a proposal submitted to the 802.11 committee by Harris and Lucent. It is a standard for a higher speed wireless LAN with data rates of 5.5 Mbps and 11 Mbps. It will have only one physical layer (DS spread spectrum with complementary code keying) for the higher date rates, and will be backward compatible with existing 802.11 equipment. If the signal between a station and an access point is too weak to support the higher data rates, the transmission rate will "downshift" to a lower rate in an effort to maintain the channel. This version of the standard will use the same Media Access Control (MAC) protocol as 802.11. This standard was approved in September 1999, and products are just becoming available.

3. 802.11 a.

802.11 a is a very high data rate wireless LAN intended for use in the Unlicensed National Information Infrastructure Band (UNII) at 5.15-5.35 GHz and the 5.8 GHz ISM band. Data rates can range from 6 to 54 Mbps. These products are not yet available.

V. **Bluetooth**

Bluetooth is a new industry standard intended to provide radio based wireless connections for devices such as mobile computers, personal digital assistants, mobile phones, and devices connected by short cables. For instance, Bluetooth radio technology built into both a cellular telephone and a laptop computer would replace the cable used today to connect them. Printers, PDAs, desktops, fax machines, keyboards, joysticks and virtually any other digital device can be part of the Bluetooth system.

Bluetooth radios use fast frequency hopping spread spectrum modulation in the 2.4 GHz ISM band. They can support an asynchronous data channel, up to three simultaneous synchronous voice channels, or a channel simultaneously supporting asynchronous data and synchronous voice. Each voice channel supports a 64 kb/s synchronous (voice) link. The asynchronous channel can support an asymmetric link with a maximum data rate of 732 kb/s while permitting 57.6 kb/s in the return direction, or a 432.6 kb/s symmetric link. The higher data rates are achievable by using a lower rate forward error correcting code option. There are three error-correction schemes defined, 1/3 rate forward error correction code, 2/3 rate forward error correction code, and an automatic repeat request (ARQ) scheme. The purpose of the error correction is to reduce the number of retransmissions. In a reasonably error-free environment, lower rate codes will be used to provide higher data rates. In multipath or interference prone environments, higher rate coding and correspondingly lower data throughput rates will be used.

Bluetooth is a technology that is being categorized as a Personal Area Network, a term that the IEEE incorporates under a new subgroup, 802.15. These technologies describe a very small network, called a piconet, which operates in the vicinity of the user or a device. The piconet consists of a collection of devices connected via Bluetooth technology in an ad hoc fashion. A piconet has at least two connected devices, and may grow to eight connected devices. When establishing a piconet, one unit will act as a master and the rest will act as slaves for the duration of the connection. Multiple independent and non-synchronized piconets form a scatternet. Devices can be registered in more than one piconet, but only eight devices can be active at any one time. Devices that are in a piconet, but not active are called parked units. These devices synchronized to a piconet can enter power-saving modes.

The Bluetooth radio complies with the FCC rules for the ISM band. Spectrum spreading is accomplished by frequency hopping in 79 hops displaced by 1 MHz, starting at 2.402 GHz and stopping at 2.480 GHz. The maximum frequency hopping rate is 1600 hops/s. The nominal link range is 10 centimeters to 10 meters, but in the future, may be extended to 100 meters with increased transmit power.

Before any connections in a piconet are created, all devices are in standby mode. In this mode, an unconnected unit periodically "listens" for messages every 1.28 seconds. Each time a device wakes up, it listens on a set of 32 hop frequencies defined for that unit.

A connection is made using a page message when the unit address is already known, or by an inquiry message followed by a page message if the address is unknown, which is the likely case for DSRC. The master unit will send a train of 16 identical page messages on 16 different hop frequencies defined for the slave unit. If no response is received, the master transmits messages on the remaining 16 hop frequencies in the wake-up sequence. The maximum delay before the master reaches the slave is twice the wakeup period (2.56 seconds) while the average delay is half the wakeup period (0.64 seconds). This is very important for DSRC use because vehicles have limited time to establish communications in ITS applications.

Bluetooth provides user protection and information privacy mechanisms at the physical layer. Connections may require a one-way, two-way, or no authentication. Authentication is based on a challenge-response algorithm. Encryption is used to protect the privacy of the connection. Bluetooth uses a stream cipher with secret key lengths of 0, 40, or 64 bits. Key management is left to higher layer software. Users requiring greater protection must use stronger security mechanisms available in network transport protocols and application programs.

Bluetooth devices will be required to support certain baseline interoperability feature requirements including radio module compliance, air protocols, and in some cases, application-level protocols and object exchange formats. Devices displaying the Bluetooth logo will interoperate with other Bluetooth devices. Bluetooth devices must be able to recognize each other and load the appropriate software to discover the higher level abilities each device supports. Device compliance will require conformance to the Bluetooth Specification. Bluetooth technology is operating system independent.

VI. HIPERLAN

HIPERLAN is a European Telecommunications Standards Institute (ETSI) standard for a high speed, high performance wireless LAN. The HIPERLAN committee responsible for developing this family of standards felt that new spectrum was needed to develop the higher data rates required for multimedia applications. The European Conference of Postal and Telecommunications Administration (CEPT) has identified spectrum in both the 5 and 17 GHz bands. Currently, only the frequencies between 5.15 and 5.35 GHz are used. In Europe, there are three channels in the 5.15-5.25 GHz band for use in countries like France and Spain, which do not have the full allocation. Countries with the full allocation have 5 channels in the 5.15-5.35 GHz band. The channel spacing is 23.5294 MHz.

In the United States, HIPERLAN products are designed for use in the unlicensed National Information Infrastructure Band (U-NII). There are 3 channels in the 5.15-5.25 GHz band, 3 channels in the 5.25-5.35 GHz band, and 3 channels in the 5.725-5.825 GHz band. For both European and US systems, the maximum radio output power is either 50, 250, or 1000 milliwatts (mw), depending on which portion of the band is used.

HIPERLAN is a family of standards. There are currently 4 types of HIPERLAN, each intended for a different set of applications. HIPERLAN Type 1 is similar in operation to the 802 family of LAN standards and is designed for local area multimedia communications. HIPERLAN Type 2 standards address wide area networking applications and incorporate Asynchronous Transfer Mode (ATM) protocols. The third type is called HIPERAccess and is designed to meet the needs of the wireless local loop. The fourth type, called HIPERLink, is designed for high-speed (155 Mbps) point-to-point links and will operate at 155 Mbps in the 17 GHz band. HIPERLAN Type 2, HIPERAccess and HIPERLink have all been incorporated into a new project known as the Broadband Radio Access Network (BRAN) project.

HIPERLAN Type 1, like IEEE 802 LANs consists of a Media Access Control (MAC) layer and a Physical Layer. One of the features that make this technology unique is that the MAC incorporates a Channel Access Layer (CAC) that can invoke priority. There are two levels of user priority (normal and high) and an assigned residual packet lifetime. The packet lifetime determines how long a packet can remain in a queue before being discarded and no longer valid for delivery. The channel access priority is calculated at each transmission attempt using the residual packet lifetime and the user priority. These priority levels are updated constantly until a packet is transmitted (out of the queue). This simplifies implementing isochronous services in support of multimedia applications.

HIPERLAN can be implemented using multiple cells. There are neighborhood discovery protocols, dynamic routing protocols, and protocols to distribute neighborhood information throughout the network. HIPERLAN acts as a distributed system and uses these protocols to determine which terminal is in which cell, and how to forward information to it. There is no formal protocol for handing off a terminal from cell to cell.

HIPERLAN has a transmission rate of 23.5 Mbps and a maximum user data rate of 18 Mbps. It uses the same type of modulation as the GSM-based European cellular network and by some Personal Communications Service (PCS) networks in the United States. Since HIPERLAN operates in the 5 GHz band, the impact of this technology may be the lowering of prices and increasing the availability of components for other systems operating in this band. Its use for potential DSRC applications requires further evaluation.

VII. HomeRF

The HomeRF working group developed the Shared Wireless Access Protocol (SWAP) to create wireless LAN products for use in the home. The working group felt that 802.11 products were overly complex for home applications, and lacked a good mechanism for supporting voice connections. SWAP combines a simplified version of 802.11 and an extension of the Digital Enhanced Cordless Telephone (DECT) protocols to create products to network consumer electronics in the home environment such as multiple computers, computer peripherals, PDAs, and cordless phones.

HomeRF products are designed to operate over a range of about 30 meters (suitable for most homes and yards). It supports up to 127 devices per network and up to 6 full duplex voice connections. It also operates using frequency hopping in the 2.4 GHz ISM band.

The HomeRF group has petitioned the FCC to add additional channel widths with associated changes in frequency hopping rates and power limits. If granted, this will result in changes to Part 15 and a change in the bandwidth, hopping rate, transmit power and performance of HomeRF products.

VIII. What are the advantages and disadvantages of using 2.4 GHz vs. 5.9 GHz?

There are two major reasons why the 2.4 GHz band is a popular choice for new technology (other than the fact that no license is required). The first is that this frequency band is available worldwide except in Japan. This creates a global market for products developed in this band. The second reason is that development and sales of Personal Communications Systems (PCS) portable phones in the 1.9 GHz band has caused prices to drop in many components that can be used in 2.4 GHz systems. These components have also been miniaturized and techniques have been developed to conserve battery power.

The advantage of operating under Part 15 is that no license is required. The disadvantage is that there is no protection against interference. There is a growing multitude of products in the ISM bands, and reliable operation is a function of how many co-channel devices are operating in the same vicinity at the same time. Bluetooth devices operating in an office populated with wireless LAN equipment, wireless telephones, remote data terminals and microwave ovens could easily experience periods of poor performance.

7. Does the technology support a sufficient number of co-located systems?

With the exception of HIPERLAN, all of the products discussed in this paper operate in the ISM bands, and the greatest concentration of products is in the 2.4 GHz band. Even though they use spread spectrum modulation, they will still interfere with each other. Direct sequence systems have good protection against narrowband interference, but not wideband interference (other DS systems or microwave ovens). Therefore, collocated DS systems use non-overlapping channels. For example, 802.11 systems can have three non-overlapping channels.

Collocated frequency hopping systems can have collisions that will require retransmission. When the concentration of collocated transmitters is on the order of 10 to 15, severe degradation can result. There is also an issue of integrating more than one technology. Devices with embedded Bluetooth transmitters (e.g. a PDA or laptop computer) that access wireless LANs (for example 802.11) have to be carefully engineered to ensure that the two transmitters, located inches apart in the same device, do not render each other inoperable.

This issue is important for two reasons. The first is that there are many instances of multiple reader DSRC installations. The second reason is ~~that~~ these technologies can become a victim of their own success. Fast food restaurants, gas stations, and other retail outlets may use these technologies for transactions such as pay at the pump and drive through ordering. Drivers of the vehicles performing these transactions may have active Bluetooth piconets in the vehicles operating their computing devices and cell phones. Intersections with gas stations and fast food restaurants on the corners can easily create a transient situation where there are hundreds of devices within line of sight, and as the number of devices increases, the performance of all of the affected networks will degrade. Success in a transaction will depend on the users being relatively stationary long enough to complete it error free. Since these are all Part 15 devices, there is no frequency coordination required between the establishments implementing these technologies.

8. Is there sufficient conservation of battery power?

Wireless LAN and Bluetooth devices have to be power efficient. They use the host device's power supply (e.g. a laptop, cell phone, or PDA). These power supplies are rechargeable, and power efficiency relates to the time between charges, which is on the order of tens of hours. DSRC tags are generally simple to install, designed to be maintenance free, and traditionally have a design life of up to five years. Commercial off the shelf wireless LAN equipment used to implement DSRC applications would likely need to be installed to derive power from the vehicle.

X. Summary

There are several wireless LAN products currently available. and several more that are expected to be introduced in the next year or two. They are designed for portable operation: terminals will change location but are expected to be relatively stationary when transmitting. Most of the products use a form of spread spectrum and operate under Part 15 of the FCC rules in the 2.4 and 5.8 GHz bands. Others are designed for use in the U-NII bands. Some of the products use combinations of data rates and modulations that will perform reasonably well in vehicles moving at slow to moderate speeds if the transaction is short enough to be completed before the vehicle leaves the communications zone. and the local interference environment is tolerable. Reliability is not guaranteed and the frequency bands used are not regulated.

The products described in this paper have the potential to be used for some DSRC applications. The products with the greatest potential are the lower data rate spread spectrum products that have a mechanism in the MAC protocol for fast acquisition of a channel. The DSRC applications that make the best candidates for implementation with these products are the ones that are performed while vehicles are either stationary or are moving at pedestrian speeds. Many groups wishing to use DSRC-type communications such as Shell Oil. Mobil-EXXON, and VISA are also looking at wireless LAN technologies to perform retail transactions from a vehicle such as pay at the pump and drive through purchasing. They have also come to the ASTM 5.9 GHz standards group seeking a potential solution based on an ASTM-based DSRC standard. The ASTM standards group is investigating the feasibility of using existing MAC protocols with a physical layer protocol optimized for DSRC at highway speeds.

ASTM has carefully compiled a list of various user requirements for approximately 40 DSRC applications. The next phase of this effort will consist of examining each of the DSRC requirements. addressing each of the issues described in section IX. and making a determination of which applications can be eliminated and which ones remain candidates for each of the technologies discussed in this paper.